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ARMORED VEHICLE VULNERABILITY TO CONVENTIONAL WEAPONS

Army Test and Evaluation Command
Aberdeen Proving Ground, Maryland

30 January 1975

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20. ABSTRACT (of the abstract entered in Block 20, if different from Report) Provides a method for overall evaluation of vehicle armor system effectiveness in protecting crew, vehicle, components, and equipment from attack by conventional (non-NBC) weapons. Includes tests for: resistance to HE projectiles, bullet splash, HEAT ammunition, land mines, shock-producing impacts, and penetration by fragments; vulnerability of vision devices; immobilization of vehicle components; and protection of personnel. Includes evaluation of compartmentalization, fire and ammunition, and protection systems.		

20. fuel fires, explosive attack, air attack, and flame weapons. Discusses test planning including interpretation of requirements, test sequencing, inspections, instrumentation, precautions, kill probability definitions, and design and use of anthropomorphic test dummies. Does not include methods of attack not specifically designed for antitank use, nor nuclear, biological, or chemical attack.

US ARMY TEST AND EVALUATION COMMAND
Aberdeen Proving Ground, MD 21005

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1. TOP 2-2-617, 30 January 1975, is changed by making the following changes:

Page A-1; delete references 11 and 13 & 10

2. Attach this sheet to the front of the reference copy for information.

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DEVELOPMENT TEST 11 (DT) - CONJON TEST OPERATIONS PROCEDURES

AMSTE-EP-702-101

*Test Operations Procedure 2-2-617

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ARMORED VEHICLE VULNERABILITY TO CONVENTIONAL WEAPONS

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SECTION I
GENERAL

1. Purpose and Scope. This TOR describes the most frequently used tests for determining the effectiveness of armored vehicles in protecting the crew, vehicle, components, and equipment from attack by conventional (non-HEAT) weapons.

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2. Background.

a. The protection that an armored combat vehicle is required to provide against enemy threats is specified in the Required Operational Capability (ROC) and the Development Plan (DP). In general, the user of an armored vehicle would prefer a vehicle in which firepower, mobility, and protection all are maximized. Since an increase in one capability often has a detrimental effect on the others, however, the designer must effect compromises, giving primary consideration to the specific mission of the vehicle. Other constraints in armored vehicle design are imposed by transportability (TOP 1-2-500), reliability, state-of-the-art, and cost.

b. The weight allocated for a vehicle's armor envelope must be apportioned according to the probabilities and severities of attack upon each vehicle area. Consideration must also be given to locating important or sensitive components in well-protected portions of the vehicle. The three major concerns in vulnerability analyses are: protection of the crew, protection of vehicle mobility, and protection of firepower. Of particular concern in this regard is protection against detonation of stowed ammunition and uncontrolled burning of the fuel, for if either occurs, the results could be catastrophic.

c. This pamphlet does not include all vulnerability tests because among the many possible methods of attack are some that are not specifically designed for antitank use. This TOP also does not include vulnerability to nuclear weapon attack which is covered in TOP 2-2-618, nor to chemical or biological attack.

d. This TOP does not stand alone. AMCP 706-170, Engineering Design Handbook, (S-NOPORI) Armor and Its Applications (I), provides extensive information on armored vehicle vulnerability that cannot be included in the TOP because of its security classification. Information is also available at the Combat Data Information Center (CDIC), Wright-Patterson Air Force Base, Ohio. In addition, there are other TOP's referenced herein which are essential to the conduct of tests of armored vehicle vulnerability. They include:

TOP 2-2-620, Resistance to Severe Shock (Armored Vehicles).

TOP 2-2-710, Vehicular Armor.

TOP/MTF 2-2-711, Armor Weldments.

TOP 2-2-715, Protection by Armored Vehicles Against Kinetic Energy Projectiles.

TOP 2-2-722, Fragment Penetration Tests of Armor.

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3. Equipment and Facilities. Equipment and facilities are described in paragraphs 4.9, 4.10, and in the applicable test phases below.

SECTION II TEST PROCEDURES

4. Preliminary Activities.

4.1 ROC/DP Interpretations. The amount of detail on armored vehicle protection requirements varies with the different ROC's/DP's. Sometimes the test director finds complete guidance on all of the levels of protection that he must consider. At other times he may be required to seek clarification from Headquarters, TECOM, as well as to avail himself of in-house knowledge and experience.

When the ROC/DP is not sufficiently definitive or comprehensive regarding protection against enemy threats, it is desirable to go beyond the threats that the ROC/DP has addressed and make a more complete vulnerability evaluation, selecting appropriate tests from those described herein.

4.2 Destructive Tests Versus Nondestructive Analyses. Though an extensive destructive test program on a vehicle will provide the maximum amount of data, such a test program rarely is conducted; the cost and time required and lack of hardware are deterrents. These factors, plus the availability of existing data, result in test and evaluation programs that are partially destructive and partially nondestructive.

Nondestructive vulnerability analyses are made by physically studying the vehicle in detail and comparing each design feature with those of other vehicles for which destructive data have been obtained previously, and using data obtained during the engineer design and research tests of the vehicle under study. Much of the data on prior vehicles is contained in reference 1 (app. A). Such studies eliminate the necessity for much firing. There are cases, however, in which ballistic tests involve low cost and do not cause much damage. In such cases (assessments of keying and bullet splash, for instance), ballistic tests are justified. At the other extreme, greatly overmatching forms of attack are usually wasteful of materiel and money.

4.3 Pretest Inspection. Before vulnerability testing the vehicle must be carefully inspected and data recorded for the following:

- a. Compliance with the ROC/DP and equipment specifications.
- b. Operations check to provide baseline data for comparing performance of the vehicle before and after specific types of attack.

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- c. Type and thickness of armor comprising the vehicle envelope.
- d. Items and components that are missing or damaged. Photographs of the interior may be taken.
- e. Determination of which assessments require destructive tests and which can be accomplished with nondestructive tests.

4.4 Stowed Ammunition and Fuel. Live ammunition is never placed in a test vehicle except when the particular subtest is specifically designed to evaluate the effect of exploding ammunition. Even then the warheads are normally inert and only the propellant and primers are live. For all other tests, completely inert ammunition is used.

Fuel is drained from the test vehicle whenever there is any danger that the fuel may ignite or the fuel cells may be punctured. The exception to this occurs when fuel ignition or fire fighting is part of the test, or fuel is required to operate a remotely controlled vehicle.

4.5 Probability of a Kill. The assessment of tank damage in terms of the probability of kill, P(K), has been standardized and is used in the United States particularly by AMSAA. Kills have been divided into mobility kill, firepower kill, and complete kill, with the following definitions:

- a. M kill. A tank suffers an M (mobility) kill if it is incapable of executing controlled movement and is unrepairable by the crew on the battlefield.
- b. F kill. A tank suffers an F (firepower) kill if the main armament is put out of action either because the crew has been rendered incapable of operating it or because the armament or its associated equipment has been so damaged as to render it inoperative and unrepairable by the crew on the battlefield.
- c. K kill. A tank suffers a K (complete) kill or is destroyed if it receives both an M and F kill, and is damaged beyond repair.

In some vulnerability tests of vehicles, the test director may be required to assess damage from each attack in terms of whether or not there was a kill and, if so, what kind of a kill occurred. Other details may be found in reference 1 (app. A).

4.6 Survivability. Survivability is the ability of a weapon system to avoid or absorb most or all attacks and still be capable of engaging and reengaging the enemy. The ability of a combat vehicle to resist debilitating damage from enemy hits is one of the elements of survivability. (The other three are: ability to avoid detection, ability to be difficult to hit when detected, and ability to be easily repaired)

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when damaged.) The determination of the vulnerability of combat vehicles in the manner described in this TOP is part of the process of evaluating survivability, prior to combat exposure.

4.7 Repairs and Maintainability. As pointed out in 4.6 above, the ability of a vehicle to be easily repaired after suffering combat damage is one of the elements of survivability. The ease with which equipment can be repaired is called maintainability and is one of the elements of the maintenance evaluation subtests (TECOM Suppl 1 to AR 750-1) routinely conducted on vehicles undergoing endurance testing (TOP 2-2-507). Since the maintenance evaluation does not ordinarily cover combat damage, a vulnerability test affords an opportunity to determine the amount of time, the spare parts, and the skills that are needed to accomplish repairs of damage resulting from ballistic attack. While complete repair of extensive damage is generally impractical, it is desirable to repair those components that are fairly vulnerable and, when damaged, have a serious effect upon the firepower or mobility of a vehicle. Examples are the track, roadwheels, and vision devices.

4.8 Test Sequence. Since each combat vehicle presents a different problem in vulnerability, test plans must be developed for the individual situation. A determination must be made regarding type of test, i.e., destructive or nondestructive, levels of priority, requirements of time, and severity of tests relative to damage and cumulative effects.

As far as possible, the tests should be conducted in order of increasing severity so that the maximum amount of data can be obtained before the destruction of the vehicle. There is always a statistical problem involved in destructive tests, especially when only one vehicle is available. Thus, care must be taken to insure securing sufficient data for firm conclusions.

The sequence of the tests can usually be better arranged after all details of the investigation have been established. A test such as protection against small arms bullet splash would ordinarily be first, and a test of resistance to penetration of the armor itself or a mine test would be among the last of a series of vulnerability investigations on a combat vehicle.

Time phasing of the various tests is planned by use of a Gantt chart (fig. 1). The "Program Evaluation and Review Technique" (PERT) may also be used in planning. It provides a more complete picture of the timing of events and the interaction between tests through the use of a network. When several events may take place concurrently, PERT shows which one is critical to completing the entire test program on time.

4.9 Instrumentation. It is desirable in some vulnerability tests to provide instrumentation to measure certain effects of the attack; for instance:

- a. Extensometer to indicate peak strain during the impact tests.

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b. Blast gages to determine the blast levels in the vehicle resulting from nearby high-explosive detonations.

c. Thermocouples and recording instruments to measure the interior temperatures of the vehicle under some attacks.

d. Accelerometers to measure the acceleration transmitted to components or dummies by ballistic attack.

e. High-speed motion picture cameras for portraying action under certain attacks, such as velocity and peak accelerations of vehicle displacement. In many cases, motion pictures are of limited value because of the obscuration caused by smoke and dust during a ballistic attack.

X = Receipt of armored vehicles.

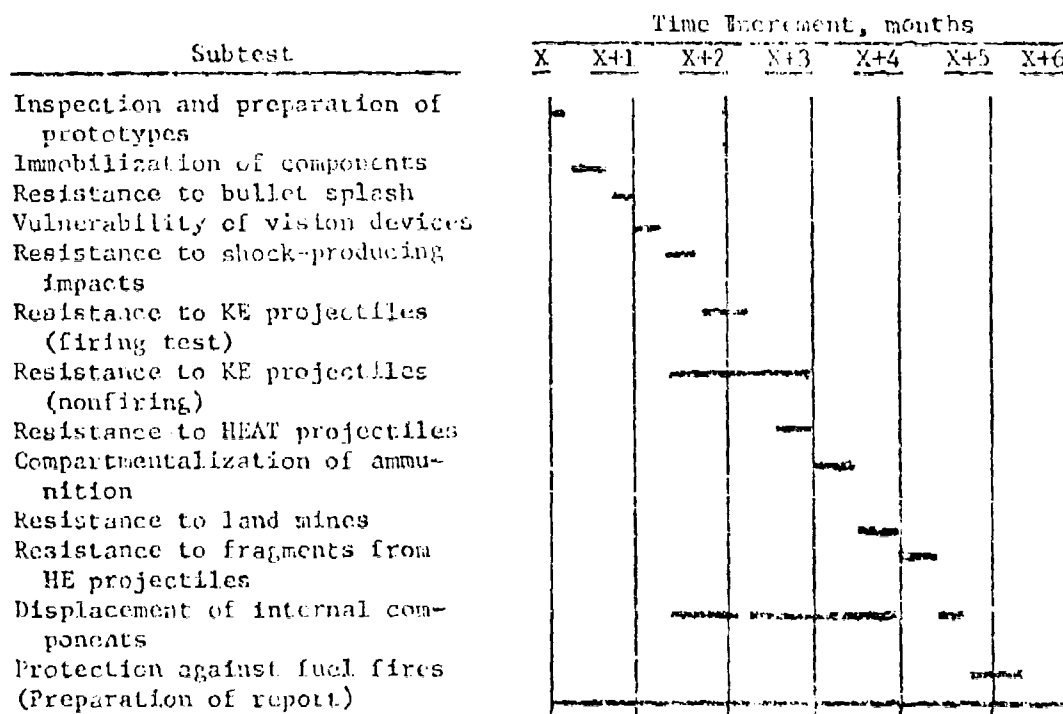


Figure 1. Example of a Gantt Chart Used for a Vulnerability Study.

f. Still cameras for photographing damage sustained by the test vehicle during the test.

NOTE: When possible, graphic presentations of data should be prepared.

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4.10 Use of Dummies for Human Simulation. In many vulnerability tests, it is advisable to place dummies in the test vehicle to represent the crew. Expendable dummies, constructed of wood or other material, should be used when an attack is expected to result in interior fire, explosions, or lethal fragments entering the test vehicle. Inspection of the dummies after each attack provides information on the casualties to be expected among crew members after various types of attacks. Nonexpendable anthropomorphic dummies, which closely simulate the human body, are used to measure accelerations transmitted to personnel by shock impacts. They are discussed in detail in appendix B.

5. Resistance to Kinetic Energy Projectiles. The objective of this test is to determine whether the armor of the vehicle meets the requirements for resistance to ballistic attack by kinetic energy projectiles. The ROC/DP will stipulate the probability with which the front, sides, and rear of the vehicle are required to defeat specified projectiles.

TOP 2-2-715, Protection by Armored Vehicles Against Kinetic Energy Projectiles, provides a detailed description of the procedures that are to be used. TACOM has a computer program that will also produce the desired probabilities. In both methods the input consists of data on the ballistic limits of each armor area from the various stipulated directions of attack. Insofar as possible, the required data are obtained from ballistic results generated in prior tests of armor rather than from ballistic tests of the vehicle under study. If complete data are not available, a limited amount of actual ballistic testing may be necessary on either the vehicle itself or on armor representative of armor on the vehicle. If ballistic testing is required, ballistic limits are obtained in accordance with TOP 2-2-710.

Ballistic limits merely provide information on which projectile velocities are required to defeat the armor wall, that is, to cause damaging fragments to be displaced to the inside of the vehicle. From ballistic tables of the appropriate projectile (or from the Firing Tables Branch of the Ballistic Research Laboratories) a specific projectile velocity can be equated with range for a projectile fired at service velocity. From all ranges up to that range the projectile can defeat the armor. This is usually all that is pertinent to an ROC/DP (see TOP 2-2-715).

The ability of a projectile to defeat the armor wall does not, however, provide information on the damage that the inside of the vehicle sustains when a projectile defeats the armor. Internal damage is dependent upon many factors, particularly the residual velocity of the projectile once it enters the vehicle, the size of the projectile, the armor type and thickness, the fragment distribution, and the location of critical vehicle components and crew relative to the direction and point of entry of the projectile or displaced fragments. Data are available on internal damage to armored vehicles tested in the past and on combat results as

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indicated in paragraph 2d. Such data are sometimes adequate, but even when they are not, they often must suffice due to the high cost of obtaining firing data, the innumerable types of attacks that are possible, and the destructive effect on the usually limited number of available targets. If actual firings are necessary, the most realistic projectiles are used and the most realistic ranges simulated. Wooden dummies and inert ammunition are placed in the vehicle. Locations of impacts are selected to obtain the most information relative to probable directions and types of attacks. Following each firing, data are recorded on the location of impact and the damage sustained by the interior components and crew of the vehicle. Each firing should include an assessment of the type of kill (para 4.5) that resulted.

6. Bullet Splash. The objective of this test is to determine whether adequate protection is furnished by the splash guards and other design features for preventing the entry of bullet splash. Minute particles of splash, i.e., fragments from impacting small arms projectiles, can enter through small clearances and have been known to make three right-angle turns before losing enough energy to be ineffective against vehicular equipment and crew.

Firing is conducted against all openings and clearances and at the edges of hatch covers or doors. The grilles of engine compartments are included; they are susceptible to the passage of splash since they are designed to allow the entrance of sufficient air to cool the engine. The clearance around the gun shield is another location where splash may enter. Testing is conducted as follows:

a. Before firing, place heavy (kraft-type) paper against the inside of each opening or clearance in the test vehicle.

b. With caliber .30, 7.62-mm, or caliber .50 armor-piercing and ball projectiles, or other projectiles as appropriate, fire at openings and clearances from various horizontal positions and realistic overhead obliquities (usually at angles not exceeding 30° from the horizontal) to determine the worst condition that could occur.

c. Record the extent of passage of splash fragments through the witness paper to give an indication of potential for injuring crew.

NOTE: In the case of engine compartment grilles, 0.020-inch-thick aluminum placed beneath the louvers serves as the witness material. Damage to the engine and any apparent effects on the engine operation are recorded.

d. Record information on direction and obliquity of attack, projectile velocity if other than service velocity, projectiles used, and location of impacts.

e. Photograph significant results.

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7. Vulnerability of Vision Devices. Vision devices on armored vehicles are not expected to withstand enemy attack without damage, but they are expected to be so designed that if they are struck by small arms projectiles neither the attacking projectile nor any resultant fragments will enter the vehicle. Included among the vision devices in question are periscopes, vision blocks, exposed portions of rangefinders, and telescopic sights.

Tests are conducted by firing small arms projectiles directly at the exposed optical devices at the prescribed simulated ranges, from the horizontal and 30° above the horizontal. Fragment entry is determined by placing 0.002-inch aluminum foil just behind the vision device in a position to catch fragments. Perforations of the aluminum foil are considered as evidence of fragments that could be injurious to personnel. Following each firing an attempt is made to replace the vision device, and the time and spare parts needed are recorded. Additional data on the vulnerability of vision devices are obtained in the fragmentation test (10 below) in the event of fragment hits on the devices.

8. Immobilization of Components. The objective of this test is to investigate the possibility that moving parts on the outside of the vehicle can become immobilized as a consequence of a partial penetration by a projectile. Immobilization is a possibility when a small clearance exists between an external moving component and a fixed surface. Immobilization can occur in several ways: by keying, in which the projectile becomes wedged between the two surfaces; by jamming (or burring) which occurs when the metal surfaces are so deformed by an impact that movement is prevented; and by locking, in which the projectile pierces one surface and partially penetrates the other surface so that they are locked together.

Fragments, as well as projectiles, may cause immobilization of some components, but fragmentation tests are not necessary because adequate information can be obtained with projectiles. Nevertheless, when fragmentation tests are conducted under paragraph 10 below, observations are made for effects that contribute to immobilization studies.

To accomplish a meaningful study of immobilization, it is necessary to investigate not only which components can be immobilized and under what conditions, but also the probability that a random hit on the vehicle from the projectile in question will cause immobilization of the particular component. Additional information on this subject is contained in reference 1 (app. A). Testing is performed as follows:

a. Position the test vehicle on an appropriate test site, preferably on a rotating table to facilitate rotation of the vehicle for all-around attack.

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b. Conduct firing against interfaces between movable and fixed surfaces. The projectile size to be used for the test should be based on the amount of clearance. Clearances of 1/2 inch or less are often immobilized by firing caliber .30 and caliber .50 armor-piercing projectiles. Immobilization tests are conducted with horizontal fire except when a particular vehicle design requires firing from slightly above the horizontal. Projectile velocities should simulate the probable combat ranges. Targets will include such areas as openings between:

- (1) Hatch covers and turret.
- (2) Gun shield and turret.

NOTE: To evaluate the possibilities of a gun shield's being rendered immobile through penetration, a projectile and projectile velocity must be selected that will be capable of penetrating the gun shield in an area where it is backed up by turret armor. Attack conditions must be realistic.

- (3) Gun tube and gun collar.
- (4) Base of turret and hull (turret ring area).
- (5) Hatch covers on hull.
- (6) Movable and immovable parts of hinges.
- (7) Suspension components.
- (8) Deflecting strips used to prevent immobilization of moving parts, if provided.

c. Record the following data for each component tested:

- (1) Component identification.
- (2) Projectile type and size.
- (3) Impact velocity.
- (4) Impact location.
- (5) Direction of attack (angle in degrees to left or right of direct front).
- (6) Effect on mobility of component.
- (7) Means by which immobilization is produced.

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(8) Projected area (square feet) from each of the four major attack directions which, if struck, will lead to immobilization (e.g., 1.2 square feet, left side).

(9) Estimated angles of attack that could result in immobilization (e.g., 45° to 130°, right side).

d. Conduct post-test operation of the test item to determine the effects of projectile damage on the test item performance as well as time for repair.

9. Resistance to HEAT Ammunition. The objective of this test is to evaluate the resistance-to-penetration of the main armor envelope against attack by HEAT ammunition. HEAT ammunition, also called shaped-charge ammunition, forms a high-velocity jet with great penetrating ability and a capability for producing fuel fires or setting off ammunition once it has penetrated the armor.

HEAT ammunition can be delivered against a vehicle by a number of weapon systems using either rockets or projectiles. Selection of the HEAT warhead should be commensurate with the vehicle's battlefield role and with the expected types of attack. For tests designed to evaluate the susceptibility of fuel and ammunition to the jet, the HEAT warhead is usually statically detonated against the protecting armor, with the warhead oriented so that the jet will strike the fuel or the propellant of stowed ammunition (see paras 13 and 14). For tests designed to determine the ability of heavy armor (all HEAT warheads can readily defeat light armor) to provide protection against specific HEAT projectiles or rockets, the warhead is usually fired at the target tank from its appropriate launcher. Tests of HEAT warheads versus armor are covered in TOP 2-2-710. In dynamic firings against armor, foreign ammunition is preferred. Because of variations in fuzing and design, the assumption cannot be made that foreign ammunition will perform in the same way as U. S. ammunition.

10. Resistance to Penetration by Fragments. The objective of this test is to assess the vulnerability of a vehicle to shell fragments. This can be accomplished by any or all of the following:

- a. Using data from previous tests.
- b. Firing fragments or simulated fragments from guns at the vehicle or mockups of sections of the vehicle.
- c. Statically detonating shell at various locations near the vehicle.
- d. Using existing computer models available at TACOM and AMSAA.
- e. A combination of one or more of the above.

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TOP 2-2-722, Fragment Penetration Tests of Armor, describes all of the test methods mentioned above.

In addition to determining the effect of the fragments on the basic armor wall, the effect on other exposed components, such as vision blocks, periscopes, gun mounts, engine compartment grilles, etc., should be observed or at least appraised. The fragmentation grenade is often employed for this purpose. Tests are generally conducted as follows:

a. Tape the grenade in position on or near the component to be tested.

b. Staticallly detonate the grenade.

c. Inspect the test item and record the following: Type and location of the grenade, type and amount of damage, and effect on the operational performance of the vehicle.

11. Welded Joint Evaluation. The objective is to verify that the weld material and the plate joint design comply with established standards and techniques and provide adequate protection against rupture.

The various armor plates that comprise the armor envelope usually are joined by welding. These welded joints must withstand not only the inherent forces due to operation of the vehicle but also the localized shock and penetration effects from various types of ballistic attacks. Ideally, a welded joint should provide the same strength as the basic armor plates that it joins. Thus, a test of welded joints involves the use of attack conditions that are fairly close to the maximum that the basic armor can sustain.

In evaluating the welded joints of an armored vehicle both shock resistance and resistance to penetration must be considered.

11.1 Shock Resistance of Welds. The steps for measuring shock resistance of welds are as follows:

a. Examine the vehicle to determine for every direction of attack whether the attack puts the weld in tension, in compression, or in shear (fig. 2). Welds are strongest if in compression (and require no test for verification) and weakest if in tension. (See also ref. 1, app. A.)

b. Examine data from prior tests of similar joints, and examine results of other tests (such as mine tests) of the test vehicle conducted in accordance with this TOP. This examination and step a above will determine the need for any additional firing.

c. If additional firing for assessing shock resistance is required, select projectiles (high-explosive or proof projectiles) in accordance with those for similar armor thicknesses as given in specifications for welded armor (refs. 3 and 4, app. A).

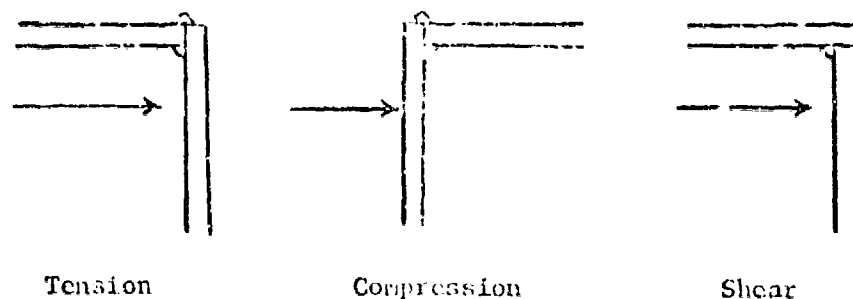


Figure 2. Reaction of Welded Joints to Directions of Attack.

d. Fire projectiles in accordance with methods of testing welded structures in TOP/MTP 2-2-711, and appraise the damage to the welds in terms of length of crack, if any, maximum displacement of the metal, and width of rupture.

11.2 Resistance to Projectile Penetrations. The following procedure is optimum for determining the ability of the welded joint to resist penetration by AP projectiles, and follows those of reference 6 (app. A). In reality, difficulties in controlling impact location and projectile velocity will require that the test director use his judgment in altering the testing procedure and analyzing the results.

a. Select AP projectiles which are the threat specified in the ROC/DP (see TOP 2-2-715). The procedure below is applicable to caliber .30, caliber .50, 7.62-mm, and 12.6-mm projectiles.

b. Fire all projectiles at a striking velocity that is one standard deviation under the striking velocity of the threat. (One standard deviation is derived from earlier data which defines the particular probability-of-penetration curve. If none exists, assume 1.5% of the ballistic limit for aluminum and 2% for steel.) Use the following procedure:

(1) Aim the weapon to impact at the junction of the weld and place two rounds on this junction.

(2) If two partial penetrations are not achieved, increase the distance from the junction by 1/4- to 3/8-inch and fire two rounds.

(3) Repeat this procedure, increasing the distance from the junction by intervals of 1/4- to 3/8-inch, until two consecutive partial penetrations have been achieved, then confirm the two partials by firing a third round at the same distance from the junction.

(4) If the confirming round causes a complete penetration, move out another 1/4- to 3/8-inch until two consecutive partial penetrations followed by a confirming partial have been obtained.

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c. Record the following:

- (1) Location and type of welded joint.
- (2) Obliquity, type, and thickness of armor.
- (3) Projectile type.
- (4) Assumed standard deviation.
- (5) Striking velocity, each round.
- (6) Distance of impact from juncture (such as corner).
- (7) Results of impact, i.e., complete or partial penetration.

NOTE: In addition to the firing just described, it is sometimes desirable to obtain a ballistic limit in the weakest portion of the joint to obtain a quantitative evaluation of the maximum loss in protection. TOP 2-2-710 discusses this type of testing in greater detail.

d. Determine the total area of the weld that can be completely penetrated by the projectile at the velocity used in this test, and use the results as part of the evaluation of armored vehicles in accordance with TOP 2-2-715.

12. Resistance to Land Mines. The objective of this test is to evaluate the damage that is sustained by an armored vehicle as a result of a land mine detonation.

A mine is a fused munition designed to function, or to be functioned remotely (command detonated), when a target comes within lethal range. Mines vary significantly in complexity and sophistication. The oldest type of mine, still in wide use, is the manually emplaced blast-type mine, functioned when the target applies a sufficient force on the pressure plate. Today, there are many fuzes with sophisticated sensing systems that may be employed with mines and may detonate the mine anywhere under an armored vehicle. Some mines are mass scatterable by artillery, missiles, or ground vehicle or aircraft dispensers. A listing of various mine and fuze features is contained in TOP 4-2-505, Mines and Demolitions.

All antitank mines rely upon explosive content for their effectiveness; some, however, may contain an explosive in a configuration that will concentrate the destructive force in one direction. Such is the case with the shaped-charge mine (Monroe effect) which contains a conical cavity in the explosive, and the plate-charge mine (Miszny-Schardin effect) in which the explosive is positioned against the convex side of a metal plate (an example is the M-21).

The blast-type mine is used primarily to immobilize an armored

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vehicle by breaking its track and causing other damage to the suspension system and nearby armor areas. It is therefore tested under the track. Mines with shaped charges or plate charges are designed primarily to perforate the floor of armored vehicles and are so tested. Since they are also damaging to suspension systems, they may also be placed under the track if targets are available. Suspension system tests and floor armor tests are described separately below. As in other vulnerability tests, data on prior tests of other vehicles should be examined to determine whether such data are adequate for making nondestructive assessment or whether actual detonation of mines is, in fact, necessary.

12.1 Suspension System Tests. Prior data on other vehicles are adequate only if the exact suspension system has already been tested on a similar vehicle. Thus, actual testing is almost always required to evaluate a new vehicle. In designing a test, the plan should provide for one of the mines to be placed in its potentially most damaging position.

Mines are least effective when detonated under the first or last roadwheel. They are most effective when detonated between roadwheels, though this location is not significantly greater than under an intermediate roadwheel. Most modern mines are fused to detonate beyond the first roadwheel of an armored vehicle.

A mine is most effective against the track when centered under the track; effectiveness decreases as the mine location moves toward the track edge; that is, inboard or outboard of the centerline. Effectiveness against the crew increases as the mine is moved inboard. The distance from the centerline is the primary variable factor considered in test design. The first mine is usually located midway between the track centerline and the inboard edge. Subsequent locations are based on the results obtained.

Soil type and condition have a pronounced influence on effectiveness. Clay, for example, significantly increases mine effectiveness, and dry sand significantly decreases effectiveness and is therefore not a suitable medium for tests of vehicles. Limited tests reported in reference 5 (app. A), using steel plates as targets, showed that 67 percent more weight of explosive is required in dry sand to produce damage equivalent to that caused in wet clay. Dry sand required 46 percent more explosive than wet sand. In general, hardness of soil increases mine effectiveness as does saturation of soil with water. Unless otherwise specified, mine tests of vehicles should be conducted in soils that tend to increase mine effectiveness; e.g., clay, moist loam, or moist loam mixed with clay. For each mine test the vehicle should be located where the soil has been compacting for many years. Mines should be buried to the prescribed depth (or placed on the surface in the case of scatterable mines). The vehicle may be in position or towed over the mine. The mine is then statically detonated from a safe distance. Some tests may require the use of anthropomorphic dummies (app. B) to evaluate the effect on personnel of the sudden movement of the vehicle. Accelerometers mounted in the vehicle near the mine location may also be considered.

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Following each mine detonation a detailed description is provided of all damage, and, where feasible, the time to repair is estimated. Instrumentation data are recorded and, when possible, interpreted in terms of harmful effects on crew members.

12.2 Floor Armor Tests. In the case of floor armor, data are nearly always available (ref. 1, app. A) on prior tests that have involved mines versus armor plate that is supported by a special fixture rather than a vehicle. Thus, it is not necessary to subject an armored vehicle to attack on its floor armor merely to see whether the floor will or will not rupture. The purpose of a floor armor test is to determine what happens to the crew and the equipment in an armored vehicle as a consequence of such an attack, and to evaluate welds that join the floor armor. As a minimum, wooden dummies and inert ammunition should be installed in the vehicle. A pretest examination is made of the condition of all components in the tank. Anthropomorphic dummies and accelerometers mounted inside the vehicle are desirable.

The mine selected is in accordance with the ROC/DP requirements. It is normally positioned under the middle of the fighting compartment, at the prescribed depth of burial, and statically detonated. Following detonation a detailed description of damage and instrumentation results are recorded.

12.3 Antipersonnel Mines. While the usual mine test is conducted with antitank mines, there may be a requirement that lightly armored vehicles be able to withstand the detonation of antipersonnel mines. Tests of this type are discussed in TOP 2-2-710 and reference 14 (app. A).

13. Compartmentalization of Stowed Ammunition. The objective of this test is to evaluate the containment of stowed main-gun ammunition to determine the extent to which the ammunition compartment inhibits the destructive effect of burning propellant. This test is usually the final test in an armored vehicle evaluation due to the potential catastrophic effects of initiated ammunition. Prior to dynamic evaluation, an investigation should be made of the inherent protection provided by the vehicle armor, interior components, and surrounding stowage containers. This protection can be then related to the penetrability of the specified threat attacks. To evaluate the effects of penetrated ammunition the following test sequence may be used as a guide:

- a. Select a HEAT warhead capable of penetrating the vehicle armor and surrounding interior components.
- b. Select and stow a desired quantity of rounds (live propellants, inert warheads) and orient these rounds so that the jet strikes the propellant.

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c. Mount necessary instrumentation such as strain gages on major armor surfaces, pressure gages in the immediate vicinity of the rounds and at the various crew stations, and temperature gages at desired locations. Camera coverage may be desired for documentation.

d. Statically detonate the HEAT warhead.

e. Inspect the vehicle and any remaining ammunition. (This should be done by demolition experts.)

f. Photograph and record results.

14. Protection Against Fuel Fires. The objective is to evaluate the susceptibility of a combat vehicle to catastrophic fire resulting from battlefield attacks and to assess the vehicle's capability to suppress on-board fires. Data relative to fire initiation developed during previous testing can be utilized in this investigation. However, differences between prior vehicles tested and the vehicles undergoing tests often justify actual testing.

Fires are most readily initiated by perforations by HEAT or incendiary type projectiles, although they are sometimes started by perforations by kinetic energy projectiles. Generally, only HEAT warheads are used since they represent the worst condition. To conduct a fire suppressant test, especially with the vehicle equipped with a chemical fire retardant, the procedures given below are followed:

a. Ensure that standby firefighting equipment is present during the test.

b. Install thermocouples at selected locations in the vehicle to measure the heat levels and time duration.

c. Install high-speed cameras at various vantage points outside the vehicle to document the fire intensity and duration.

d. Install instrumentation to measure the concentration of the fire suppression agent and the pyrogenic byproducts of combustion at various locations in the vehicle.

e. Bring fuel temperature to operating level either by running the engine or by artificial methods.

f. Ignite the fuel tanks preferably by statically detonating a HEAT projectile against the armor nearest the fuel. The projectile should be aligned so that the jet will enter the fuel tank.

g. During the fire at regular intervals, sample the atmosphere inside of the vehicle at various locations for concentrations of fire suppressant and fire byproducts.

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h. Observe and record all characteristics of the fire.

i. Measure and record the time for initiation of the fire suppression system and duration of the fire.

j. After the fire is extinguished and fresh air is introduced, determine and record the extent of fire damage.

For additional information in comparing vehicles or in complying with ROC's and DP's the following should be determined:

a. Protection provided by the vehicle armor envelope or other components relative to areas of greatest fire susceptibility.

b. Techniques and locations of fire detectors (i.e., optical, heat sensor, or grid systems).

c. Location, size, and type of extinguishing agent of automatic fire extinguishers.

d. Location, size, and type of extinguishing agent of portable fire extinguishers.

e. Locations and effectiveness of exterior pull handles for onboard fire suppression systems.

f. Type of engine fuel (TOP 2-2-701) and relative flash point.

g. Type classification and flammability of any extensive quantities of hydraulic fluids and oils.

Reference 12 (app. A) discusses in detail the above described test.

15. Protection Against Explosive Attack.

15.1 HE Projectiles. HE projectiles are not designed to be employed against armored vehicles, but sometimes they are used in lieu of other more conventional antitank weapons. Of most concern are the 105-mm and 155-mm HE projectiles. A test consists of firing one or more of these projectiles at a tank and recording the damage. Firing is normally at the turret and at a point at which there will be some confinement of the blast, thereby increasing the chances of damage.

15.2 HEP Projectiles. HEP projectiles are especially designed to be employed against armor. The HEP projectile is not expected to develop a hole in armor but rather to cause a large steel spall to be displaced from the inside of the armor wall. The projectile crushes against the outside wall of the tank and explodes, precipitating a shock wave

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through the armor that causes the spall to be displaced from the interior wall at up to several hundred feet per second. Data on the ability of HEP projectiles to defeat (cause spalling of) armor of various obliquities and thicknesses are available from earlier tests. From prior data it is possible to predict the damage that an HEP projectile can impose, and it is therefore unnecessary to fire HEP projectiles at the tank under study. If HEP projectiles are to be fired, careful observations must be made of all damage incurred both inside and outside of the tank. Accelerometers within the tank can provide useful additional data.

15.3 Offensive Grenades. Offensive grenades, which are essentially throwable containers of high explosives, are sometimes used in tests of armored vehicles to determine in an inexpensive, and only mildly destructive, way how various components on the outside of a tank can withstand blast per se. The grenade is taped in position near the component in question, such as a vision block, periscope, thin armor section, grille, hatch cover, or gun mantlet, and statically detonated. Damage caused by the grenade is recorded.

16. Resistance to Shock-Producing Impacts. Tests involving the resistance of an armored vehicle to shock from impacting projectiles are covered in TOP 2-2-620. Many of these tests are designed to employ proof projectiles or sacrificial armor so that the armor of the vehicle will not be damaged. Anthropomorphic test dummies (both 50 and 95 percentile) which may be used in connection with these tests are described in appendix B.

17. Displacement of Internal Components. If not properly mounted, components that are attached to the inside walls of armored vehicles may be displaced (i.e., broken off) by projectile impacts that would otherwise be defeated by the armor wall. If displaced, such components could become secondary missiles traveling at a velocity sufficient to injure crew and damage other components. Thus, internal components should be mounted on brackets, shock mountings, or welded tapping blocks that are able to withstand impacts from projectiles that are defeated by the armor wall and mine detonations.

Special firings are not conducted to evaluate shock mountings of internal components. Instead, the mountings are visually examined and assessed, and data are accumulated during the course of other tests - especially those involving projectile impacts (paras 5, 8, 9, 11, 15 and 16) and those involving mines (para 12). Following each attack, inside components are examined for damage and displacement.

18. Protection Against Air Attack. Air attacks include strafing fire from automatic weapons, attacks by HE and HEAT rockets, attacks by HE bombs, and attacks from jellied gasoline (napalm). In a vulnerability analysis, however, rarely will it be necessary to actually employ aircraft as delivery weapons.

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18.1 Strafing with Automatic Weapons. Strafing fire is different from ground attack in that the direction of attack is from above (assume up to 30° above the horizontal) and the speed of the aircraft and gravity contribute to the velocity of the projectile. The most efficient method of conducting a strafing test is to simulate the target-threat relationships. This can be achieved by ground firing either by using an elevated firing position or by tilting the test vehicle. The latter is generally the most acceptable. Two factors are considered:

a. First, obtaining the ballistic limit of the pertinent armor sections from attacks above the horizontal. As required, the maximum velocity in the test could exceed the standard muzzle velocity of the weapon by an amount that would take into consideration the velocity of the aircraft and the contribution of gravity. This will to some extent be offset by the drag on the projectile caused by the distance between aircraft and target. Ballistic limits are obtained by the method described in paragraph 5 and in TOP 2-2-710.

b. Second, the effect of projectiles that can actually enter the vehicle. To test for this effect it is necessary to fire projectiles to impact at the realistic maximum velocity that would occur under actual strafing attacks. The use of wooden dummies and inert stowed ammunition is appropriate for this test. Damage from each projectile is described in detail.

18.2 Small Rockets. Aircraft, both high performance aircraft and helicopters, may be armed with rockets with HEAT warheads expressly designed for antitank use. Aircraft may also mount HE rockets designed for use against personnel and light materiel but which may occasionally be used against armored vehicles in lieu of other weapons. In either case, tests, if necessary, may be conducted from the ground in accordance with paragraphs 9 and 15.

18.3 Bombs. In the case of heavy bombs or very large rockets it may be assumed that the probability of hitting an armored vehicle is very small and that, if an armored vehicle is hit, the vehicle will be destroyed. Thus, dropping bombs is unnecessary.

18.4 Jellied Gasoline (Napalm). Napalm is dropped from aircraft in containers of 100 gallons or more. Upon impact the napalm ignites causing a very large fireball. Though not designed primarily for use against armored vehicles, the possibility of such attacks should not be ignored. An actual test of napalm versus an armored vehicle is not normally necessary, however, because of the availability of data from prior tests of armored vehicles. Nevertheless, if such a test is required, the following procedure is followed:

a. Rig the vehicle so that it can be remotely controlled.

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b. Install thermocouples with recording devices inside the test item. Close to possible points of entry place material that will smolder but not flame.

c. Start the vehicle, close the hatches and remotely operate the vehicle at slow speed.

d. Drop the napalm in standard containers from aircraft to impact against the moving vehicle. For the test to be considered valid, either a direct hit must be obtained or the container should impact on the ground close enough to envelop the tank in flame.

e. Photograph the test from two angles with possible use of internal cameras.

f. If the vehicle engine is suffocated, attempt to start as soon as practicable.

g. Observe and record the following:

(1) Location of impact of napalm container with respect to test item and extent of vehicle coverage by flame.

(2) Duration of fire.

(3) Extent of damage to test vehicle.

(4) Indications of any entry of napalm through openings in the vehicle.

(5) Internal temperatures.

(6) Difficulty in restarting if engine was suffocated.

19. Protection Against Flame Weapons.

19.1 Molotov Cocktail. The Molotov cocktail is a fire-producing, close range, antitank field expedient used mostly in guerilla warfare. It can be prepared by filling a glass container with a mixture of lubricating oil and gasoline, with a wick protruding out of the opening. A test consists of remotely propelling the lighted Molotov cocktails in the vicinity of the test vehicle openings. Observations are made as to whether the burning mixture enters the test item and causes it to catch fire or would cause injury to the crew. Damage is recorded and preventive measures suggested.

19.2 Flamethrowers. A stream of burning fuel could be directed at an armored vehicle from a flamethrowing vehicle or a hand-held flamethrower though this would be an unusual use for a flamethrower. If a test is

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deemed necessary, it is conducted in the same general manner as the napalm test (para 18.4). If the vehicle is adjudged able to resist attack by napalm, however, it may be assumed that it can also resist attack by flamethrowers.

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APPENDIX A
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APPENDIX B
ANTHROPOMORPHIC TEST DUMMIES

1. Design.

a. The design goal for anthropomorphic test dummies is to obtain adequate human-like biomechanical responses to impacts with high repeatability and reproducibility of test results.

b. The model VIP-50A and VIP-95 anthropomorphic test dummies manufactured by Alderson Research Laboratories, Inc., have been designed to comply as fully as possible with SAE specification J 963 and to meet additional requirements imposed by Federal Motor Vehicle Safety Standard (FMVSS) 5208 for the testing of passive restraint systems manufactured between 15 August 1973 and 15 August 1975.

c. The models available at Aberdeen Proving Ground are designated as either 50 or 95 percentile (i.e., at least 50 percent (or 95 percent) of the United States adult male population is the same size or smaller than the test dummy). Both models have provisions for the installation of instrumentation in the head, chest, and femur regions, and are normally supplied in the sitting position. The model VIP-50A, however, can be converted to the standing position by means of a modification kit.

d. Available manuals contain specific data for each individual dummy, including:

(1) A Certification Form, giving all dimensions, weights, motion ranges, resistive torques, and chest-load characteristics.

(2) An Assembly Form, indicating the types of instrumentation mountings and specific design changes incorporated within the unit.

(3) Drawings applicable to each particular dummy.

2. Parts Identification.

a. The upper parts of the upper arms, forearms, and lower legs, and the hands and feet are designated as molded parts. The skeletal members inserted in these parts are not normally supplied as spares, since they require that skin and flesh be molded about them at the factory. However, the skin and flesh section of the upper leg can be removed by slipping it out from the skin after the lower leg has been removed.

b. The head and head-back are molded assemblies. Skull and skull-backs are not normally supplied separately, since skin and flesh must be molded about them at the factory.

c. The entire mechanical neck can be ordered as a unit from the skull to the base of the neck, including mounting screws.

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d. Similarly, a complete rubber neck can be ordered, together with mounting hardware. The two necks are interchangeable.

e. The pelvic structure is designated as a molded assembly. The pelvic skeleton is not normally shipped separately since skin and flesh must be molded about it at the factory.

3. Maintenance and Repair.

a. No lubrication or similar maintenance procedures are required; it is advisable, however, to check out joint torques before a test and to inspect the entire dummy for damage after a test, particularly where high impacts are involved.

b. Many parts can be replaced by the user by welding, straightening, etc. Minor flesh tears and cuts can be repaired by use of the special electric iron provided in the toolkit. This iron is plugged in (note - only 115-volt irons are provided) and allowed to reach maximum temperature.

c. A supply of patching material is provided in the toolkit, together with scrap material that can be used for practice.

4. Application to Testing.

a. Anthropomorphic dummies may be used in connection with shock tests of armored vehicles (such as those described in TOP 2-2-620), mine tests of armored vehicles (as described in this TOP and TOP 4-2-505), and crash tests of vehicles (TOP 2-2-508). Dummies currently available, however, are designed for use with passive restraint systems and they do not simulate the resistance that the human being would exert if the body is subjected to a sudden force.

b. The instrumentation used in dummies is primarily accelerometers except that load cells are used in the femur. The US Army Human Engineering Laboratory and the US Army Surgeon General should be contacted for aid in translating g levels to damage to the human being.

c. Anthropomorphic dummies should not be used if the dummy is in danger of destruction by fire or fragments. For such applications, wooden dummies are suitable.